CLAIMS

1 A tooling system comprising:

a plurality of elongate elements each having an upper surface, said elements being arranged in an array to present said upper surfaces for machining by cutting tool means;

support means for supporting said elements, each said element being supported on said support means for axial movement between upper and lower positions relative to the other elements in the array thereby to enable adjustment of the vertical position of said element surface;

and clamping means for clamping the array of elements in a closed position in which the elements contact one another for enabling the free ends of the elements to be machined to produce a desired surface contour.

2 A tooling system as claimed in claim 1 further comprising:

drive means for moving the elements of the array between said closed position in which the elements contact one another, and an open position in which at least one selected element is spaced from adjacent elements for enabling axial adjustment of said selected element;

and adjustment means for adjusting the axial position of each element such that the upper surfaces of the elements define approximately said desired surface contour.

3 A tooling system as claimed in claim 1 or 2 wherein:

said support means comprises a plurality of supporting rails arranged parallel with one another;

each said support rail supports a plurality of elements;

and said support rails are movable laterally relative to one another.

4 A tooling system as claimed in claim 3 wherein said drive means includes means for gripping said support rail.

5 A tooling system as claimed in claim 4 wherein each said rail has locating means at each end thereof engageable by said gripping means.

6 A tooling system as claimed in any of claims 2 to 5 wherein said adjustment means comprises means for engaging and holding an element thereby to enable adjustment of the element position by said adjustment means.

7 A tooling system as claimed in any of claims 2 to 6 wherein said adjustment means comprises a fork having a head portion, and a plurality of spaced tines depending from the head portion for engaging an element, the tines defining an adjustment area corresponding to the area of an element of the array.

8 A tooling system as claimed in claim 7 wherein the fork comprises a substantially square head portion and a respective tine depending from each corner of said head portion, the tines defining an adjustment area corresponding to the area of an element of the array.

9 A tooling system as claimed in claim 7 or 8 wherein the position of the tines is adjustable relative to one another to accommodate a plurality of differently sized elements.

10 A tooling system as claimed in claim 7, 8 or 9 wherein each tine comprises:

a first section adjacent to the head portion and having an inwardly facing surface which together with the inwardly facing surfaces of the other tines defines an adjustment area;

and a second section remote from the head portion and having an inwardly facing guide surface.

11 A tooling system as claimed in claim 10 wherein the inwardly facing guide surface of the second section of the tine is convex.

12 A tooling system as claimed in 10 or 11 wherein said first section of each tine is substantially triangular in cross-section, leading to said second section, the inwardly facing surface of which tapers towards the free end of the tine.

13 A tooling system as claimed in 12 wherein the square head portion is adjustable in size, so that the tines can be moved relative to one another to define a plurality of differently sized adjustment areas, corresponding to differently sized elements.

14 A tooling system as claimed in any of claims 2 to 13 further comprising:

a tool holder for receiving said cutting tool means, said tool holder being supported for movement in orthogonal x, y, z directions wherein x and y represent orthogonal axes in a horizontal plane and z represents the vertical axis;

and drive means for moving said tool holder in said orthogonal directions.

15 A tooling system as claimed in any of claims 1 to 14 wherein:

each said element has a plurality of sides arranged such that in said closed position of said array each side abuts a side of an adjacent element;

said elements are supported on said support means in rows;

said support means is adjustable to enable a selected element to be spaced from adjacent elements thereby to enable said axial adjustment of the selected element.

16 A tooling system as claimed in claim 15 wherein:

each said element is substantially square in cross section;

said elements are formed in a diamond array and are supported on said support means in rows in which the elements of a row are aligned along a diagonal of each element;

said support means is arranged to enable each row of elements to be moved laterally relative to each adjacent row;

and each element is supported on said support means for rotation about its longitudinal axis thereby to enable said axial adjustment of the element.

17 A tooling system as claimed in any of claims 1 to 16 in which the elements are constructed from an upper portion, and a lower portion, the upper portion being removable and machinable.

18 A tooling system as claimed in any of claims 1 to 17 in which in a closed position said array presents a continuous upper surface.

16 A tooling system as claimed in any of claims 1 to 18 wherein each said element is supported on said support means such that the height of said element is adjustable in a screw-threaded manner.

17 A tooling system as claimed in claim 19 wherein each said element is supported on said support means by a screw threaded axial rod engaged in a screw threaded bore in said support means.

18 A tooling system as claimed in any of claims 1 to 19 wherein each said element is supported on said support means by electric or electromagnetic means, hydraulic or pneumatic ram means for adjusting the height of said element.

19 A tooling system as claimed in any of claims 1 to 18 wherein said clamping means has an element contacting face which is adapted selectively to apply localised pressure to one or more elements of the array.

20 A tooling system according to any of claims 1 to 19 wherein the elements of the array are substantially polygonal in cross section.

21 A tooling system as claimed in claim 20 wherein the array is substantially triangular, rectangular or pentagonal in plan view and clamping means are provided on at least two adjacent sides of the array.

22 A tooling system as claimed in claim 20 or 21 wherein the elements of the array are arranged so that, in the closed position of the array, the major axes of adjacent elements are aligned and their vertices touch one another, so that the elements of the array tessellate.

23 A tooling system as claimed in claim 21 or 22 wherein said array is substantially rectangular in plan view and clamping means are provided on at least two adjacent sides of the rectangular array.

24 A tooling system as claimed in claim 23 wherein clamping means are provided on all four sides of the rectangular array.

24 A tooling system as claimed in claim 23 or 24 wherein the outer edges of the rectangular array are serrated and the clamping means has a correspondingly serrated face.

25 A tooling system as claimed in any of claims 1 to 24 wherein the face of the clamping means contacting the array is formed from a plurality of teeth, at least some of which teeth are adjustable in order selectively to apply localised pressure to one or more elements of the array, in line with the sides of the elements.

26 A tooling system as claimed in claim 25 wherein the teeth are also individually adjustable in height relative to one another.

27 A tooling system as claimed in any of claims 1 to 26 wherein the clamping means comprise two sets of clamps, the first of which is used during machining of the elements of the tooling system and the second of which is used when the elements of the array have been

machined and the system is being used as a mould.

28 A tooling system as claimed in any of claims 1 to 27 wherein the clamping means are modular in design, so that individual clamping sides interlock with one another to form larger units.

29 A tooling system as claimed in any of claims 1 to 28 further comprising vibrating means for vibrating the clamp sides to assist in bedding down the elements of the array.

30 A tooling system as claimed in any of claims 1 to 29 further comprising sensors for detecting and measuring the forces applied to the elements of the array.

31 A tooling system as claimed in any of claims 1 to 30 further comprising means for securing the clamping means in position around the array of elements.

32 A tooling system as claimed in any of claims 1 to 31 wherein said clamping means are adjustable in height relative to the height of said elements.

33 A method of tooling using a tooling system as claimed in any of claims 1 to 32 comprising:

storing existing data representing the contour of the surface of each element including the z values of the surface at any given x,y coordinate point relative to a datum;

storing new data representing a desired contour for the surface of each element position in the array including the z values of the surface at said any given x,y coordinate point relative to said datum;

comparing said new data for a first, selected element position with the existing data for a first element in said selected element position;

and adjusting the height of said first element to adjust said z values of said existing

data at said any given x,y coordinate point to values at least equal to said z values of said new data at said any given x,y coordinate point.

34 A method as claimed in claim 33 further comprising repeating the steps of comparing said data and adjusting the height of the element for each element position and element in said array.

35 A method as claimed in claim 33 or 34 wherein said data includes the gradient and rate of change of curvature of the surface.

36 A method as claimed in any of claims 33 to 35 further comprising providing a preselected height adjustment offset for said elements in said array.

37 A method as claimed in any of claims 33 to 36 further comprising:

supporting said elements for axial movement between upper and lower positions relative to the other elements in the array thereby to enable adjustment of the vertical position of said element surface;

and clamping the array of elements in a closed position in which the elements contact one another for enabling the free ends of the elements to be machined to produce said desired surface contour.

38 A method as claimed in claim 37 further comprising moving the elements of the array between said closed position in which the elements contact one another, and an open position in which at least one selected element is spaced from adjacent elements for enabling axial adjustment of said selected element;

gripping said support rail by engaging said gripping means with said locating means

and adjusting the axial position of each element such that the upper surfaces of the elements define approximately said desired surface contour.

39 A method as claimed in any of claims 33.to 38 further comprising engaging and holding an element thereby to enable adjustment of the element position.

40 A method as claimed in claim 38 wherein each said element has a plurality of sides arranged such that in said closed position of said array each side abuts a side of an adjacent element;

and the step of adjusting the height of a selected element comprises adjusting the position of adjacent elements to space said adjacent elements laterally from said selected element thereby to allow movement of said selected element.

41 A method as claimed in claim 40 wherein said elements are arranged in rows in said array and the step of adjusting the height of a selected element includes laterally separating the row containing the selected element from the next adjacent rows.

42 A method as claimed in claim 41 wherein the step of laterally separating the row containing the selected element from the next adjacent rows comprises:

determining the position of the row within the rows in the array;

and where the number of rows to be moved exceeds a preset value, moving a smaller number of rows in turn until said selected row is moved.

43 A method as claimed in claim 41 or 42 wherein each said element is shaped in cross section such that rotation of an element relative to adjacent elements in a row spaces said element from said adjacent elements.

44 A method as claimed in claim 43 wherein spacing each said element from an adjacent element in a row comprises rotating each said element through a preselected angle.

45 A method as claimed in claim 44 wherein said preselected angle is 45 degrees.

46 A method as claimed in any of claims 33 to 45 wherein each said element is rotatably supported and the height of said element is adjusted by rotation of said element.

47 A method as claimed in claim 46 wherein the step of adjusting the height of said element comprises comparing said existing data for the element with new data for the element position and rotating said element through a preselected angle to rotate the surface of the element into a position where the existing data approximates closest to said new data.

48 A method as claimed in claim 47 wherein said preselected angle is one of 90°, 270° and 180°.

49 A method as claimed in any of claims 33 to 48 wherein

each said element is substantially square in cross section;

and said elements are formed in a diamond array and are supported in rows in which the elements of a row are aligned along a diagonal of each element.

50 A method as claimed in any of claims 33 to 49 further comprising storing further data representing the new surface contour of the adjusted elements prior to machining.

51 A method as claimed in claim 50 further comprising machining the surface of the elements of the array after adjustment in dependence on the difference between the desired surface contour and the actual surface contour.

52 A method as claimed in claim 51 further comprising comparing the amount of material to be machined from an element with a reference value and replacing said element with a plurality of smaller elements in dependence thereon;

and adjusting the height of each said smaller element to adjust z values of existing data for said smaller elements to values at least equal to z values of said new data for said smaller element positions.

53 A method of tooling using a tooling system as claimed in any of claims 1 to 32 comprising:

storing existing data representing the existing contour of the surface of each element of at least one existing array including the z values of the surface at any given x,y coordinate point relative to a datum;

storing new data representing a desired contour for the surface of each element position in a new array including the z values of the surface at said any given x,y coordinate point relative to said datum;

comparing said new data for a first, selected element position with the existing data for at least a first element in the or each said existing array;

and in dependence on said comparison:

(i) where the existing surface of one of said existing arrays approximates closest to said desired surface, selecting said existing array for machining and adjusting the height of each element of said existing array to adjust said z values of said existing data to values at least equal to said z values of said new data;

(ii) where the existing contour of the surface of an existing element of at least one existing array approximates closest to said desired surface, selecting said existing element and moving said existing element to said selected element position in said new array for machining, and adjusting the height of said existing element to adjust said z values of said existing data to values at least equal to said z values of said new data;

(iii) where the existing surface of an existing element at said first, selected element position approximates closest to said desired surface, adjusting the height of said existing element to adjust said z values of said existing data to values at least equal to said z values of said new data.

54. A method as claimed in any of claims 33 to 53 further comprising the step of aligning the elements within the array relative to each other after they have been adjusted in the z plane so that, when closed, the array has no gaps within it.

55. A method as claimed in claim 54 in which the elements are aligned automatically.